national accelerator laboratory

TM-634
1600.000

SMALL SOLENOID TEST OF INSULATION METHOD

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December 8, 1975

A set of small solenoids were built and tested to investigate the effect of various methods of insulation on their performance. MCA 23-strand unsoldered superconducting wire was used to wind solenoids with 6 layers and 9 turns each layer. All solenoids were wound on a 2-inch diameter mandrel and were about 2-7/8-inches long. The exact length depended on the thickness of the insulation, but did not vary by more than 40 mils. No banding was used.

The parameters of interest are maximum field relative to short sample results, training requirements, stability after training and ramp rate dependence. The results of individual solenoids are summarized in Table I.

The Results of Solenoid Tests

The first and third solenoids were duds, i.e., they reached 35% of short sample on the first and all subsequent quenches. The probable cause of this poor performance was shorts, although none were evidenced when the solenoids were warmed up and autopsied. Both solenoids were rebuilt and retested.

The rebuilt first solenoid 6F, which had the standard barber wrap with B-stage, had six training quenches before it reached and consistently quenched at values between 102% and 104% of short sample. It's training curve is shown in Figure 1. It is believed the failure of the first solenoid 6A represented a learning process on the part of the builder rather than an inherent deficiency in the method of insulation.

The rebuilt third solenoid 6C[1] had it's initial quench at approximately the same current as its predecessor's initial quench. After extensive training, the solenoid reached about 75% of short sample. Then followed a period of erratic behavior with the solenoid finally settling down to a consistent quench current of about 30% of short sample. This erratic behavior seems due to a short in the coil. The wire in this solenoid 6C[1] was covered on one side with spray-on epoxy, then barber pole wrapped with B-stage. A different solenoid, 6B, was wound with wire epoxy-painted on both sides. This solenoid exhibited much training compared with other acceptable solenoids, as shown in Figure 1. The spray-on epoxy appears to cause excessive training in magnets and does not aid much, if at all, in insulating the wires. All but the above mentioned solenoids eventually went slightly above (1-4%) short sample data, but the other parameters varied considerably. The amount of training ranged from 4 to 40 quenches.

Most samples showed no ramp rate dependence, as shown in Figure 2, but one, 6D, exhibited a 1000 amp decrease in maximum current with an increase of ramp rate from 90 amp/sec to 450 amp/sec (100 amp/sec <=> 17.8 GeV/sec). The cause of this large ramp rate dependence in 6D is unknown. Lack of cooling can probably be ruled out since another solenoid, 6B, which was solidly potted with Vaseline and hence had no internal cooling showed much less dependence. Two solenoids potted with epoxy and reported earlier[1], are included in Table I for comparison.

These solenoids all had transfer functions of approximately 8kG/1000 amps. Since the power supply had a maximum current of ~5400 amps, it was necessary to apply an external bias field using a large 70 kG solenoid to quench the magnet after training was complete.

The solenoids were trained as much as possible with no bias, then any additional training was accomplished at a positive bias of 20kG. After that, ramp rate dependence was run with a 10kG positive bias. Finally a few quenches were run with a 30kG bias. The points thus obtained form a curve which lies on or slightly above the short sample curve.

Several solenoids were allowed to warm to room temperature overnight, then retested. These retained a high degree of their training, taking only a couple quenches to reach the previous day's values.

Summary

From these results it can be concluded that the long used barber pole wrap with B-staged glass tape (6F) is acceptable, if the glass tape is wrapped very carefully.

Another solenoid which had a layer of mylar applied to one side and to the edges in addition to the barber pole wrap with B-stage (6E) showed the best performance.

The difference in performance between this and the previously mentioned solenoid is probably negligible, but the addition of mylar should ensure the elimination of casual shorts. Therefore, based on our testing, this would be the preferred method of insulation.

Both methods (6F and 6E) show no degradation in ramp rate dependence up to about 350 GeV/sec.

Wire with sprayed on epoxy showed excessive training and did not reach the short sample data value.

Acknowledgement

We wish to thank W. Hanson and his people for the many hours they spent building these solenoids.

Reference

1. M. Price, et al, "Short Sample Test Data IV," Fermilab TM-587, June, 1975.

TABLE I

SOLENOID TEST RESULTS

MCA 23 Strand	Insulation	Training	Final Value	Ramp Rate Dependence
6A	Bare Wire, Barber Pole with B-Staged Glass Tape	--	35% SS	
6F ($6A^1$)	Bare Wire, Barber Pole with B-Stage. Mylar Inserts where Shorts are Possible. Repeat of 6A	6	100% +	No
6B	~1 mil Epoxy Paint all over and Barber Pole with B-Stage	~15	~100% SS	No
$6B^1$	Lightly Potted (Vaseline)	No	~ 97% (-150 amp)	No
$6B^{11}$	Well Potted (Vaseline)	No	~ 94% (-300 amp)	Yes
6C	~1 mil Epoxy Paint on One Side and Barber Pole with B-Stage	--	35% SS	
$6C^1$	Repeat of 6C	~55	30% SS	
6D	 B-Staged Glass Tape; Plain Glass Tape	~40	100% +	Yes
6E	.9 mil Mylar Wrapped on Edges and One Side, Barber Pole with B-Stage,	4	100% +	No
Other Strand				
3	Bare Wire, Barber Pole with B-Stage, 17 strand, soldered	4	100% +	No
	Potted (Rigid Epoxy)	~20	95%	Yes
4	Bare Wire, Barber Pole with B-Stage, 17 strand, soldered	1	100% +	No
	Potted (Semi-flexible Epoxy)	1	87%	Yes

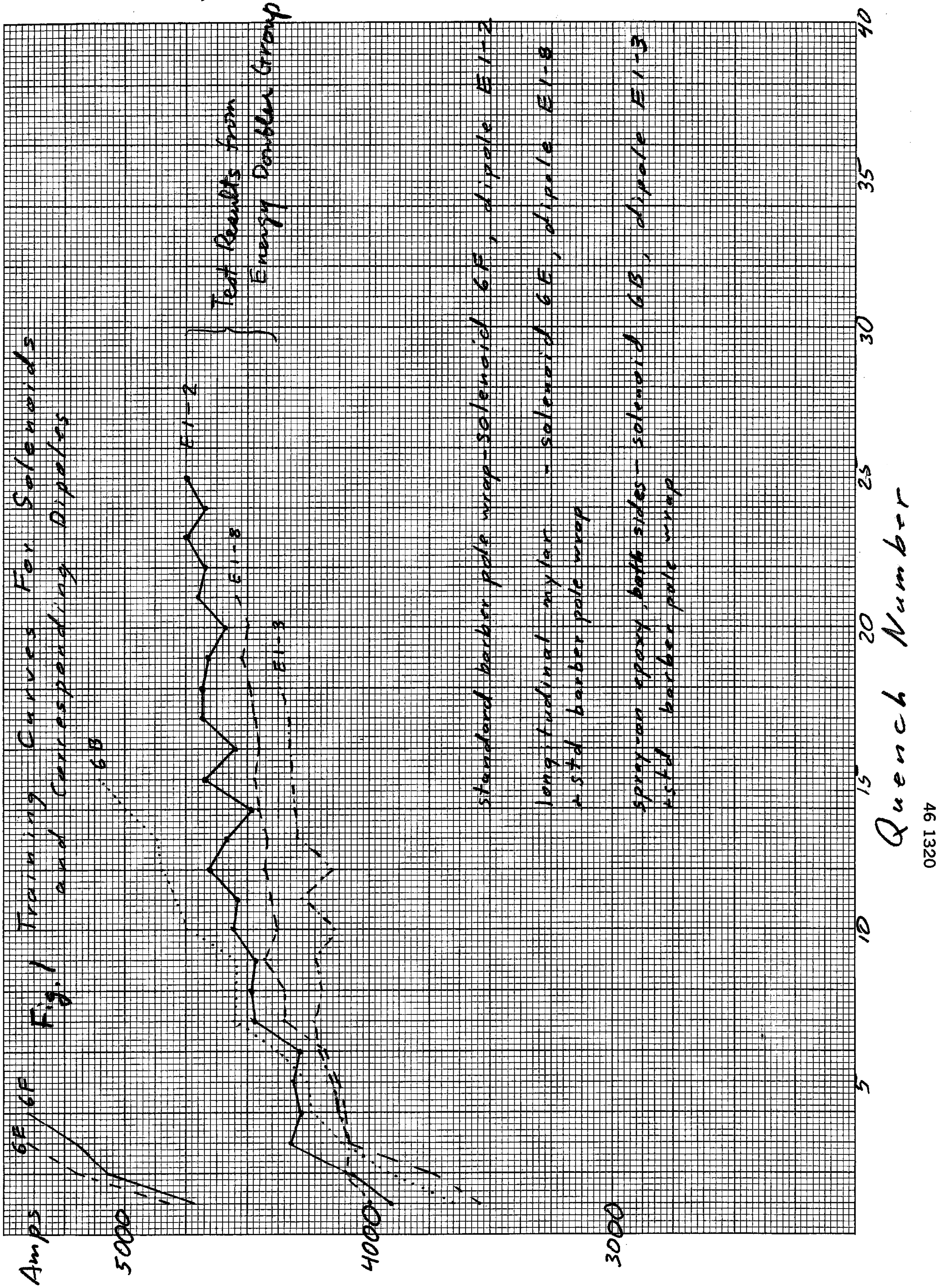
Fig. 1 Training Curves For Solenoids
and Corresponding Dipoles
Amps
5000
4000
3000
Quench Number
5
10
15
20
25
30
35
40
6E
6F
6B
E1-2
E1-8
E1-3
Test Results from
Energy Doubler Group
standard barber pole wrap - solenoid 6F, dipole E1-2
longitudinal mylar - solenoid 6E, dipole E1-8
+std barber pole wrap
spray-on epoxy, both sides - solenoid 6B, dipole E1-3
+std barber pole wrap
46 1320

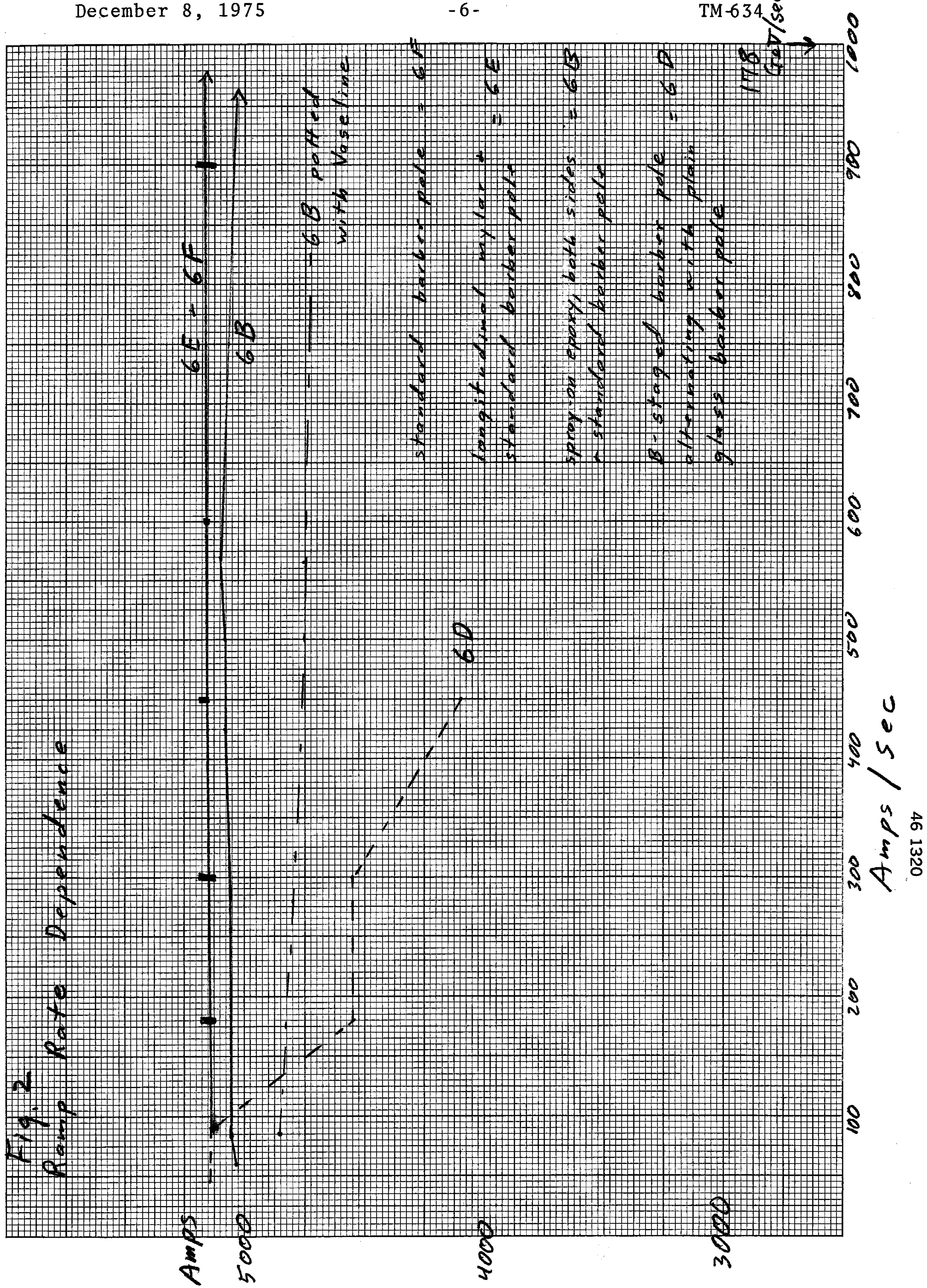

Fig. 2
Ramp Rate Dependence